Validation of 10-Year (2004-2014) SAO OMI Ozone Product with Ozonesonde and MLS Observations

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AUAR Science Meeting
08/31/2016 Rotterdam, the Netherlands

Outline

- Motivation and introduction to OMI PROFOZ product
- Validation with ozonesonde data
- Validation with MLS data
- Summary
- Updates for next version of SAO retrieval algorithm

Introduction

- SAO ozone profile product (PROFOZ) has been available at Aura AVDC since May 2014.

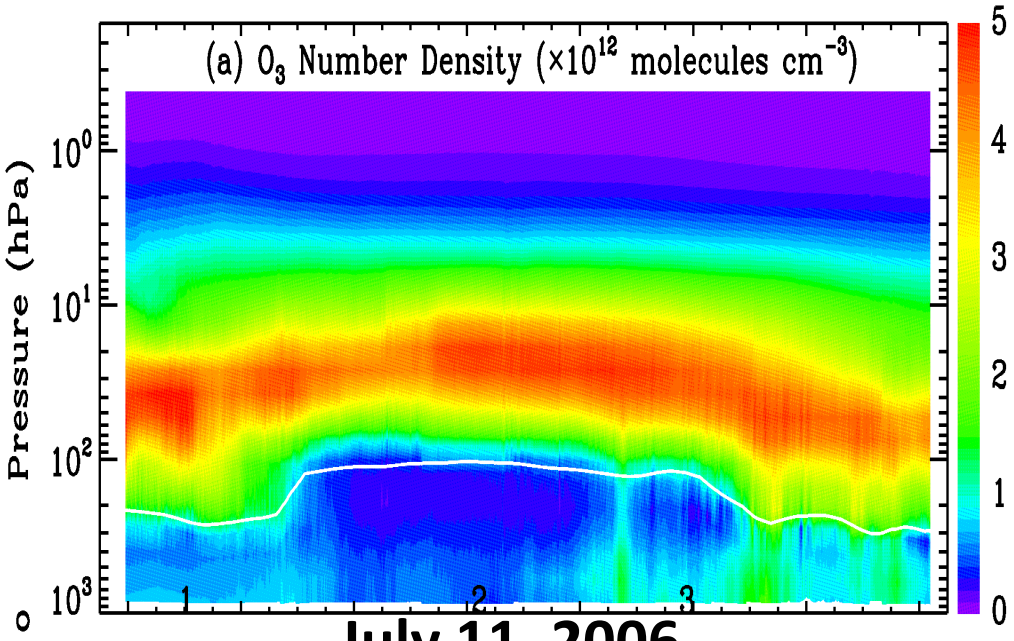
- **With 10+ years of data, what is the data quality and long-term stability?**
- **➔Evaluate the need to perform time-dependent soft calibration for next version.**

- **How is the quality affected by row anomaly? Row anomaly likely affects UV 1 data (therefore stratospheric ozone) at most cross-track positions.**

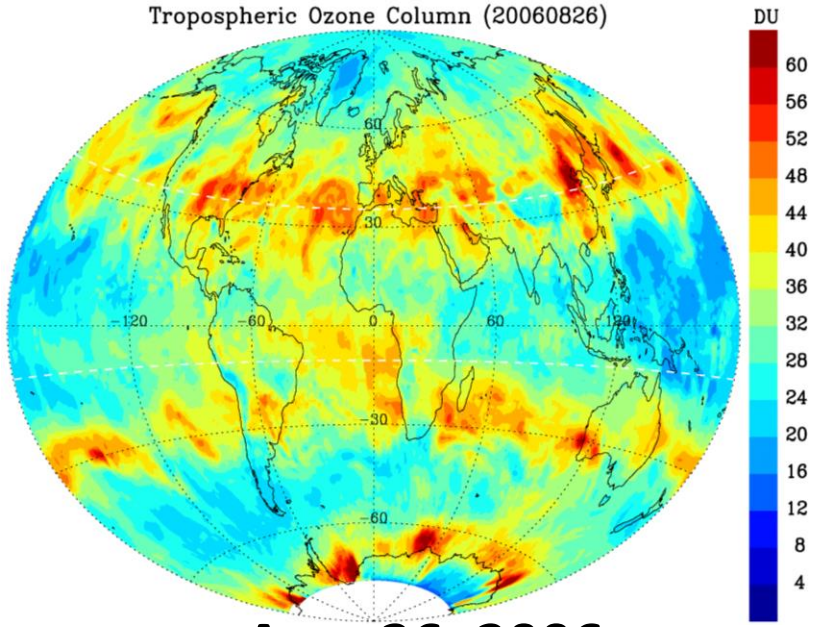
- We validate 10-year of our OMI PROFOZ product (10/2014-12/2014) using ozonesonde and MLS data.

Introduction to SAO OMI PROFOZ Product

- O_3 Profile Retrieval (Liu et al., 2010)
  - O_3 at 24 layers up to ~60 km from OMI radiances in 270-330 nm
  - Optimal estimation with LLM climatology (McPeters et al., 2007)
  - 3-year mean solar irradiance
  - Soft radiometric correction (independent of time & space)
- PROFOZ: Liu et al. (2010) with 2 major modifications
  - 4X binning along the track to speed up processing 52×48 km2@nadir
  - A minimum floor noise of 0.2% in UV2 to stabilize retrievals



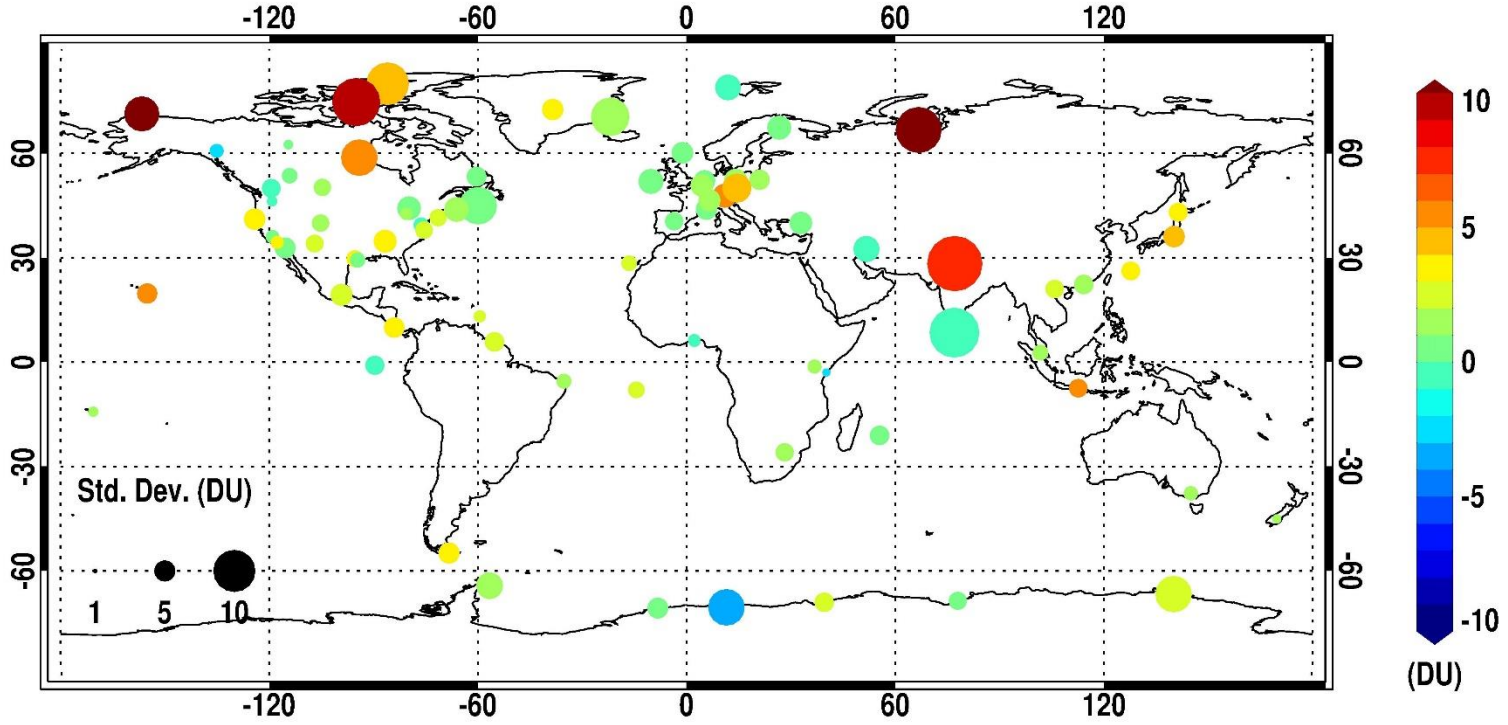
July 11, 2006



Aug. 26, 2006

Validation with Ozonesonde Data

- Ozonesonde data over the globe (2004-2014).
- ~ 100 ozonesonde stations, including those from field campaigns, was obtained from Aura AVDC, WOUDC, SHADOZ, DISCOVER-AQ, etc.
- ~ 27,000 ozonesonde profiles.

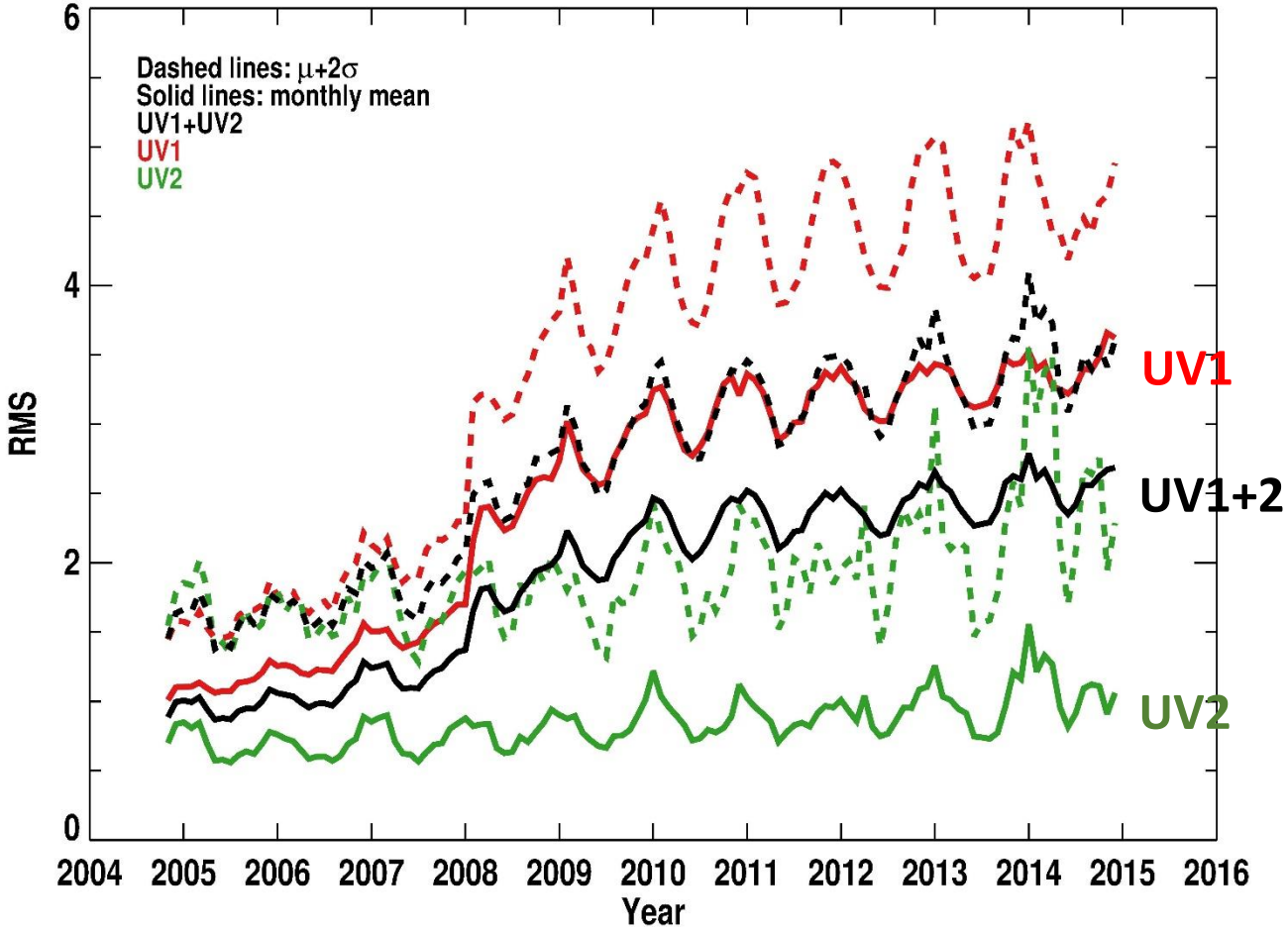


Comparisons between OMI and ozonesonde Trop. ozone columns

Validation with Ozonesonde Data

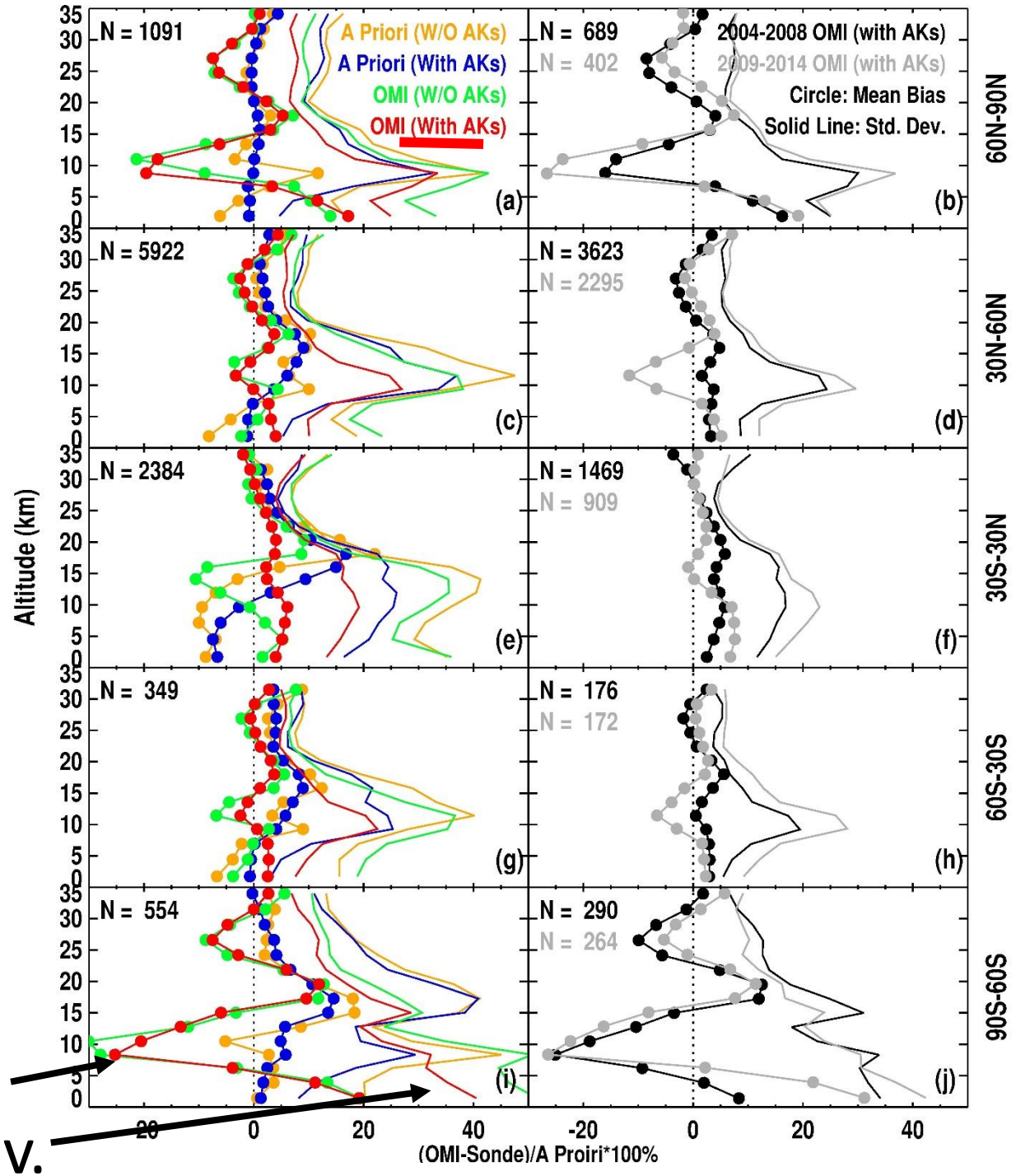
Key Thresholds	
Distance	< 100 km (nearest coincident pair)
Time	< 6 hours
R.M.S.	Monthly mean+ 2σ
Cloud Fraction	< 0.3
Cross-Track	4-27
SZA	< 75°

- Fitting RMS increases with time
- Ozonesonde profiles are convolved with OMI Averaging Kernel (AK)

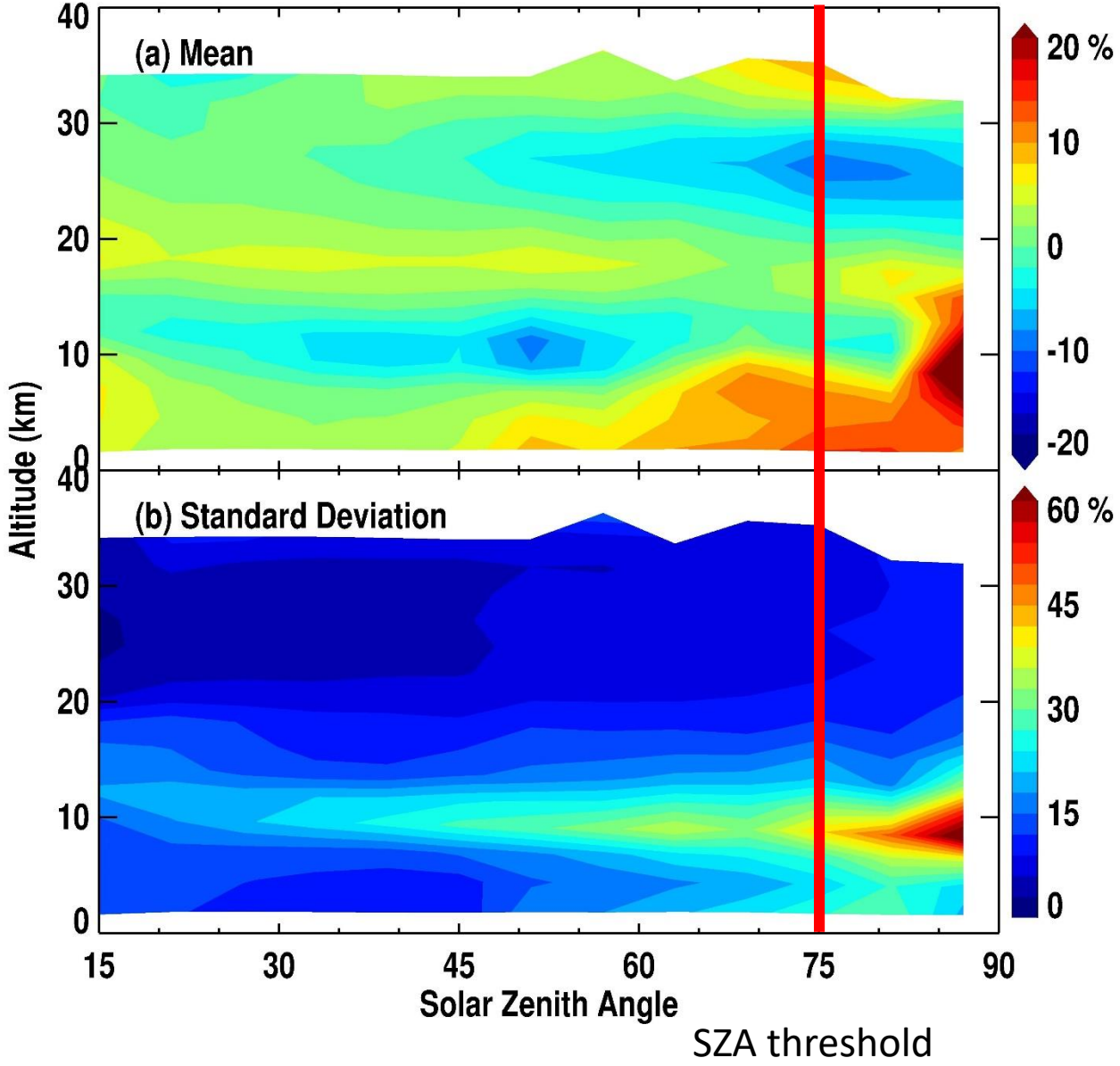


Profile Comparisons

- Three periods: 2004-2014, 2004-2008 & 2009-2014 (before & after the anomaly).
- Better agreement in the mid-latitudes and tropics than in the high latitudes.
- Biases are within 10% in mid-latitudes and tropics, with 0-25% standard deviations.
- Low mean biases above 20 km in the high latitude regions.
- 2004-2008 shows better results than 2009-2014 with smaller standard deviations.

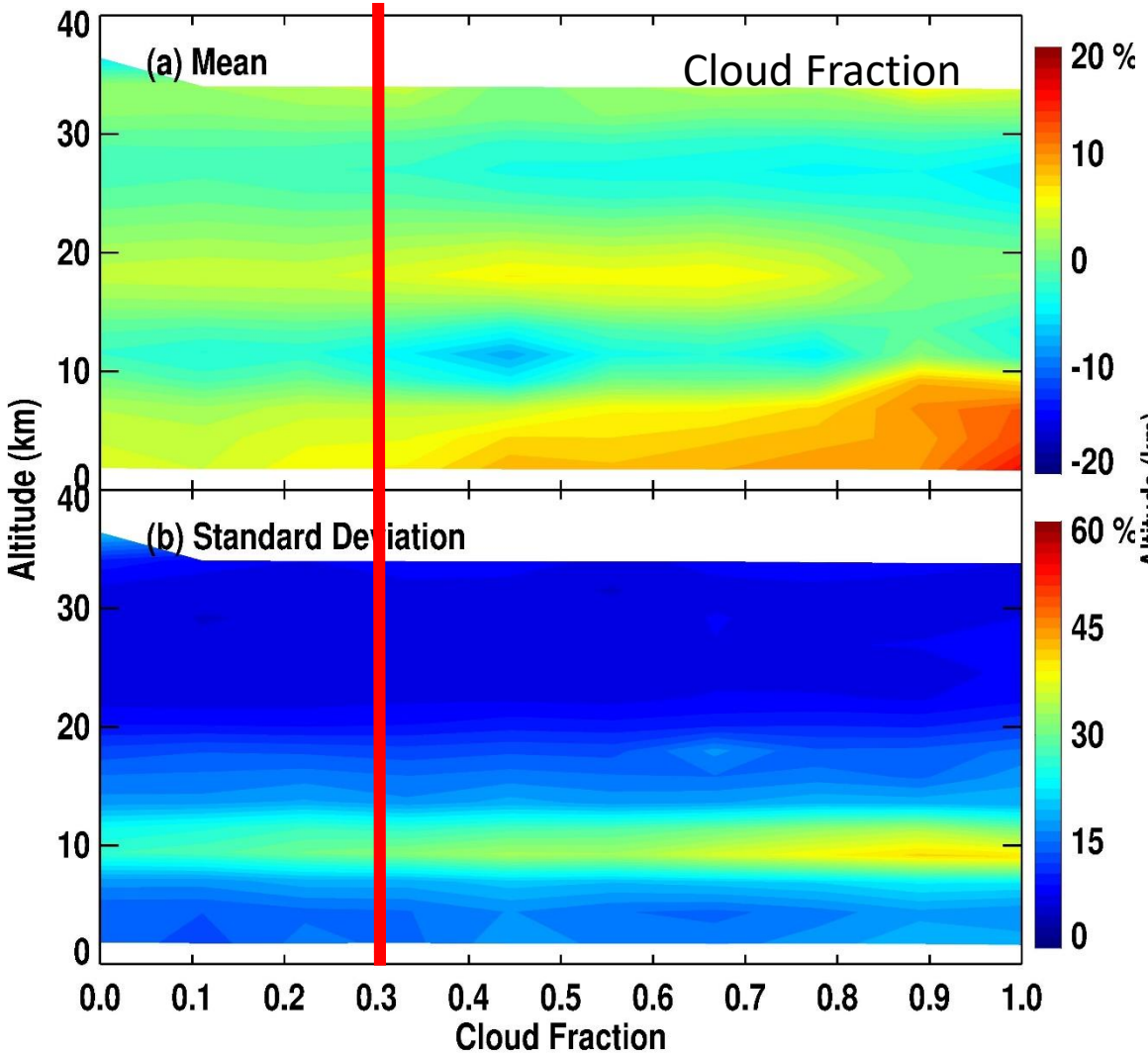


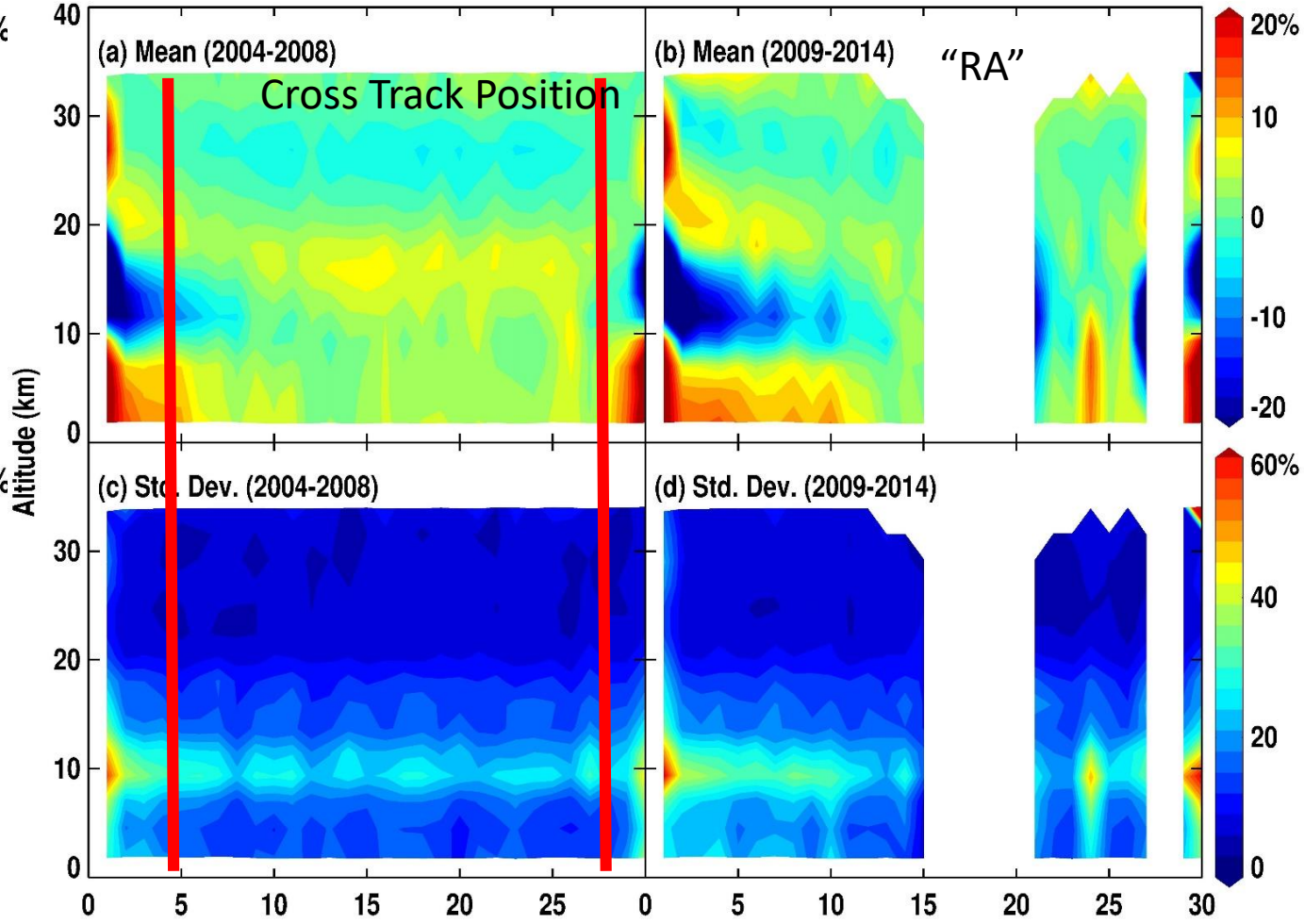
Solar Zenith Angle Dependence



- Poorer comparison (larger biases or altitude dependence, larger standard deviations) at larger SZAs.
- At large SZA, the measured backscattered signal becomes weak due to weak incoming signal and long path length
- Measurements are subject to relatively larger radiometric errors such as those from stray light and as a result of weaker signal, and radiative transfer calculations can lose accuracy at larger SZA

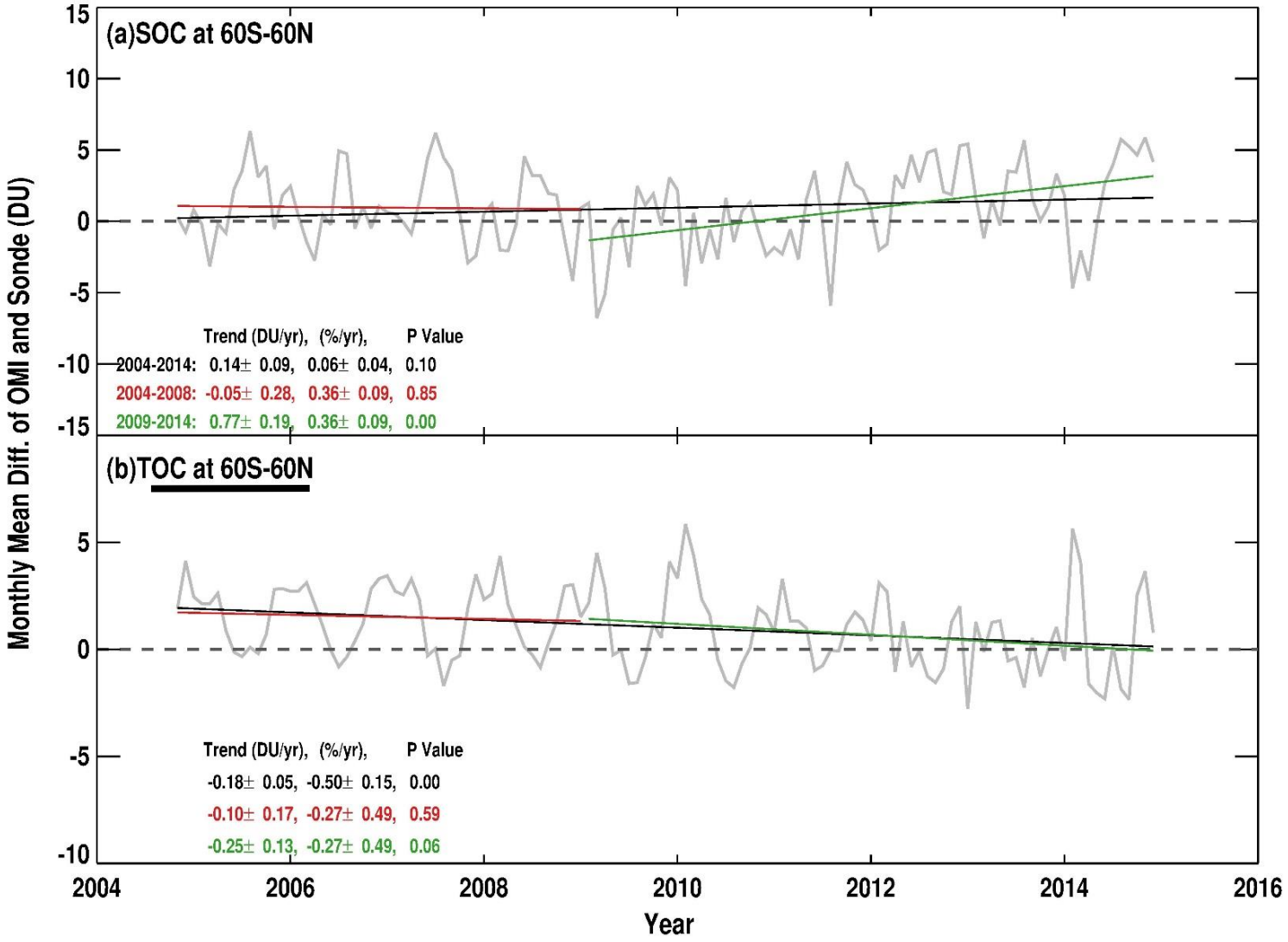
Cloud Fraction/Cross Track Position Dependence





Poorer comparison (larger biases or alt. dependence, larger std. dev.) for extreme off nadir positions and larger cloudiness.

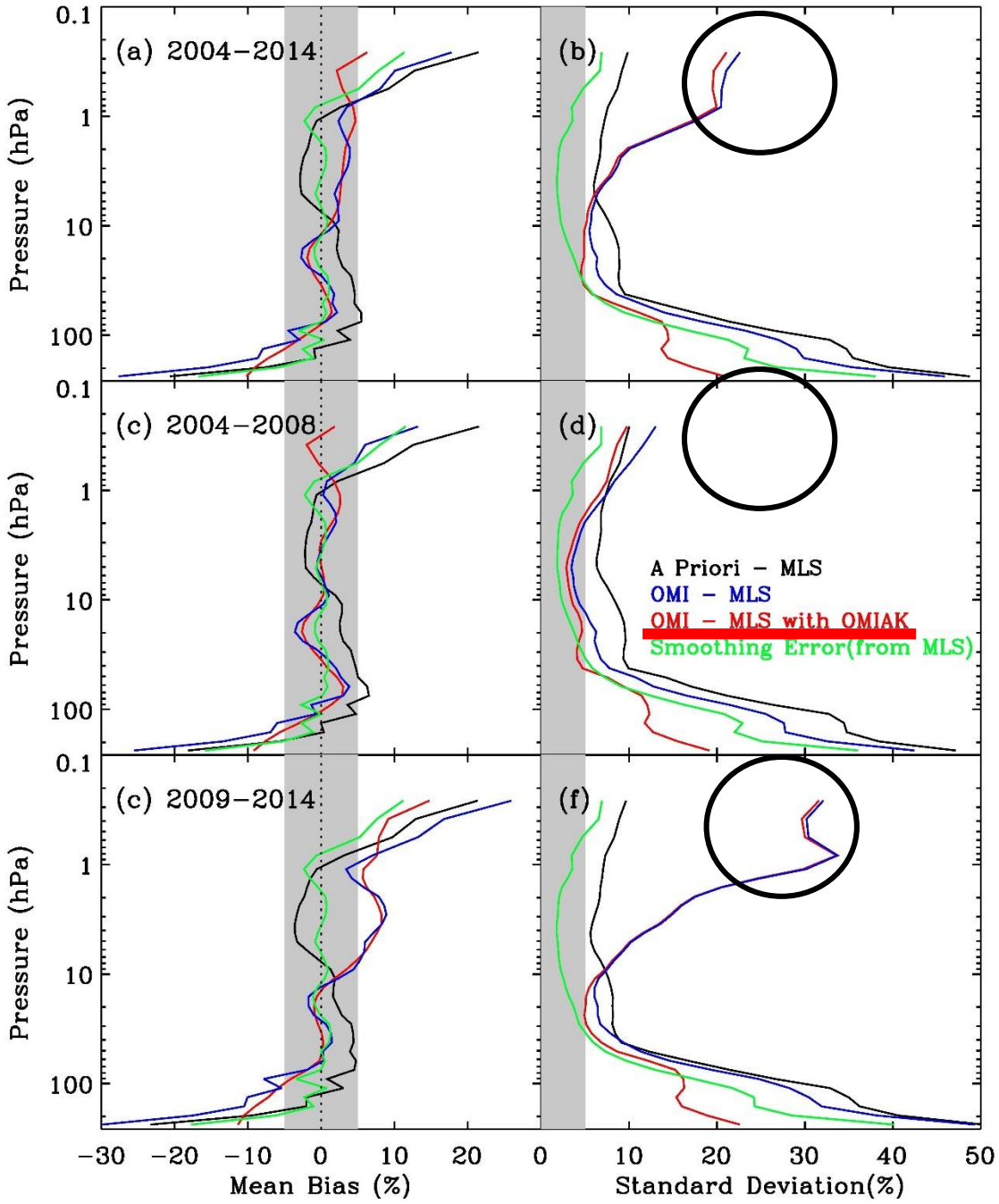
Trends of Partial Ozone Column



- SOC monthly means indicate different patterns in 2004-2008 and 2009-2014.
- SOC trends in integrated columns are less significant due to cancellation.
- TOC indicates significant negative trend.

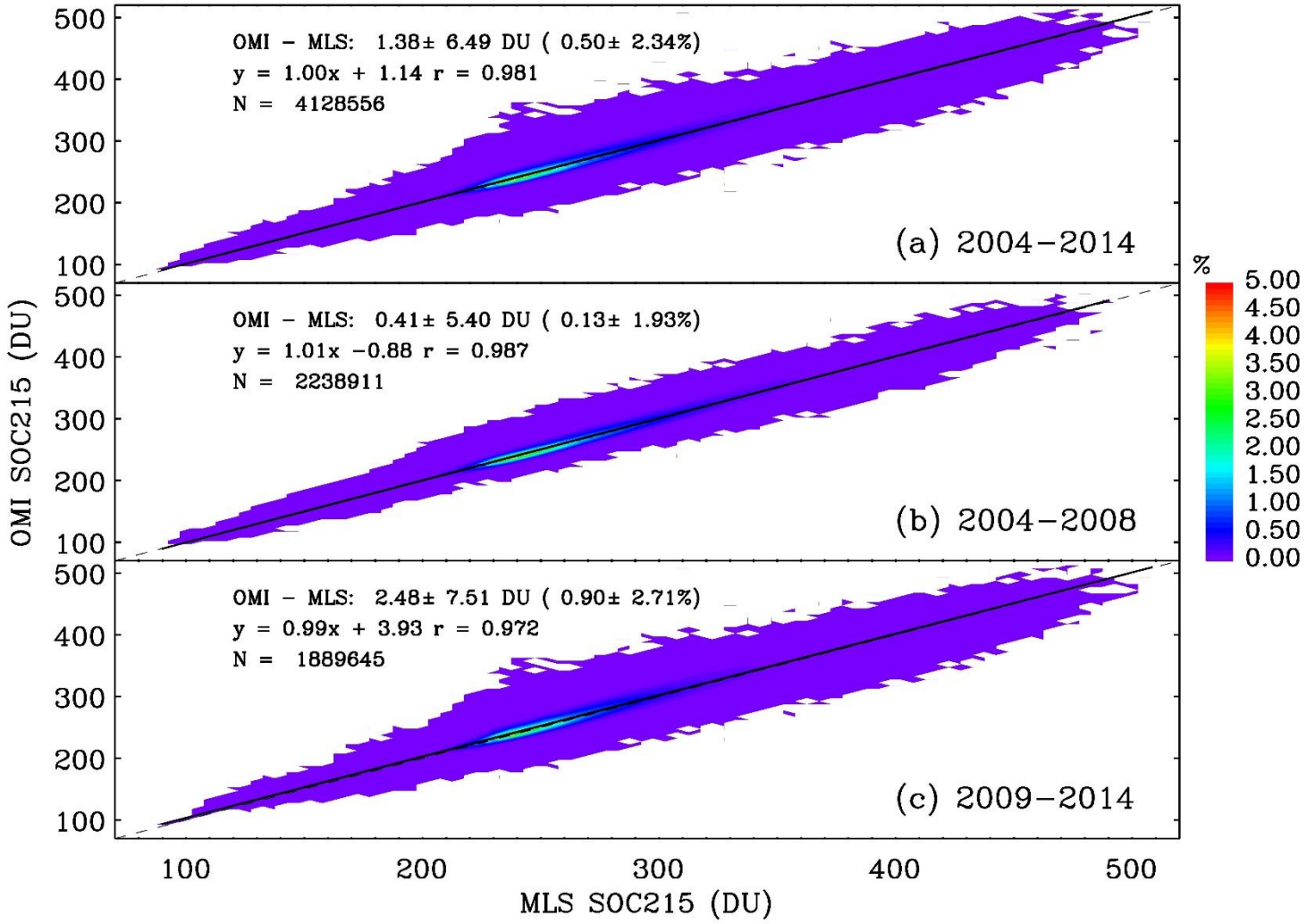
Validation with MLS

- MLS v4 data.
- 7-10/2011 are not included due unreasonable large biases likely due to the RA.
- Good agreement in 2004-2008 and similar to (Liu et al. 2010) using MLS v2.2 data.
- Large impacts of RA in the top layers.
- Global mean biases generally within 5% for with OMI AK, with 1σ of 5% at 1-30 hPa, increasing to 20% above 1 hPa and to 20% at 215 hPa.



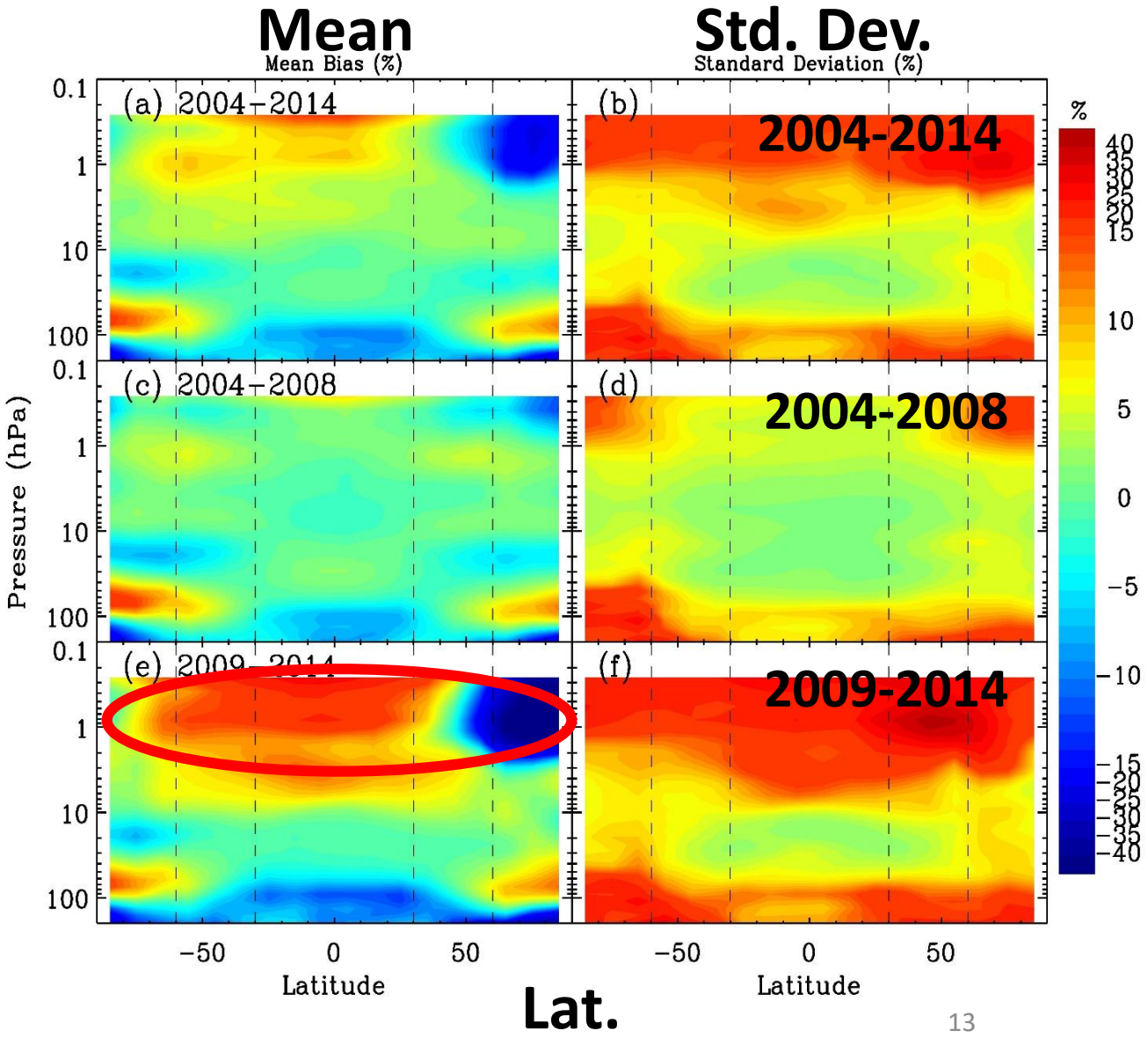
Validation with MLS

- Similar results in the three periods.
- Mean biases in SOC down to 215 hPa: 1.38 ± 6.49 DU or -0.50±2.34% in 2004-2014.
- 0.42 DU ± 5.40 DU or0.13 ± 1.93% in 2004-2008
- Slightly worse in 2009-2014: 2.48 ±7.51 DU or 0.90±2.71%.
- The RA has more impacts in profiles than the integrated columns.



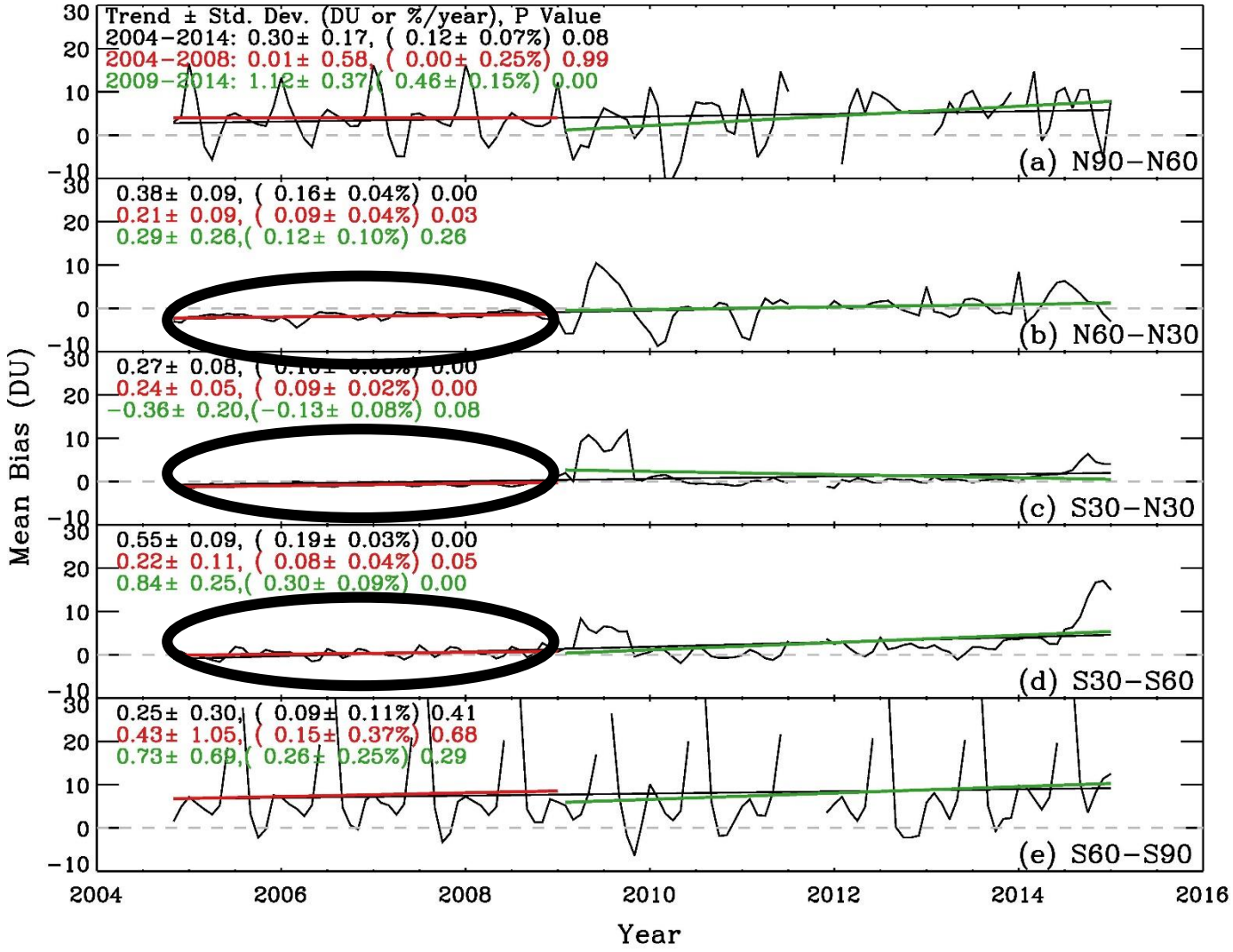
Latitudinal Dependence

- Much larger positive biases at P < 1 hPa over 70S-20N, much larger negative biases at P < 7 hPa in N. high latitude in 2004-2014.
- Larger 1σ at < 5 hPa and > 100 hPa
- These results indicate UV1 is affected by row anomaly even it is not flagged for UV2.



Trends of Stratospheric Ozone Columns (SOC215)

- Much larger mean bias variations in 2009-2014, esp. in the mid- and low latitudes.
- Trends in 2004-2008 are small but significant due to low variations.
- Large biases in 2009 have significant impacts in the trend calculations in 2009-2014.
- These large biases are likely caused by the RA pixels that may not be correctly flagged.



Summary

- **Generally good agreement with ozonesonde, especially in the tropics and middle latitudes.**
- **Larger standard deviations and temporal variations in 2009-2014 than those in 2004-2008.**
- **Retrieval biases at individual show statistically significant trends and typically different trends for 2004-2008 and 2009-2014 periods.**
- **2004-2008: Very good agreement with MLS during 2004-2008. 2009-2014: Still good agreement in strat. ozone column, but much worse in the profile comparison at high altitudes, N. high latitudes, and for some months.**
- **The results indicate that row anomaly affects UV-1 for non-flagged pixels and suggest the need to perform time-dependent soft calibrations.**

Retrieval Updates

- **Tropopause-based climatology (Bak et al., 2013)**
- **Simultaneous retrieval of PMCs with ozone (Bak et al., 2016)**
- **Independent cloud retrieval based on RRS (345-365 nm) and O2-O2 absorption (~361 nm) (Poster by Cai et. al.)**
- **OMI slit functions with on-orbit characterization (Talk by Sun et. al.)**
- **Improve retrieval sensitivity to lower tropospheric ozone using longer wavelengths to derive wavelength-dependent surface albedo**
- **Perform soft calibration vs. time and fit spectra of stray-light and systematic fitting residuals**
- **Speed up and improve the accuracy of RT calculations:**
  - PCA tool developed by R. Spurr,
  - Several lookup tables are being built to correct for RT approximations
- **Investigate effects of aerosols and sfc. BRDF on ozone profile retrieval**

Thank you

Acknowledgements

- Support from NASA Aura
- Ozonesonde providers and managers
- OMI and MLS Science Team

Additional slides

Validation with Ozonesonde Data

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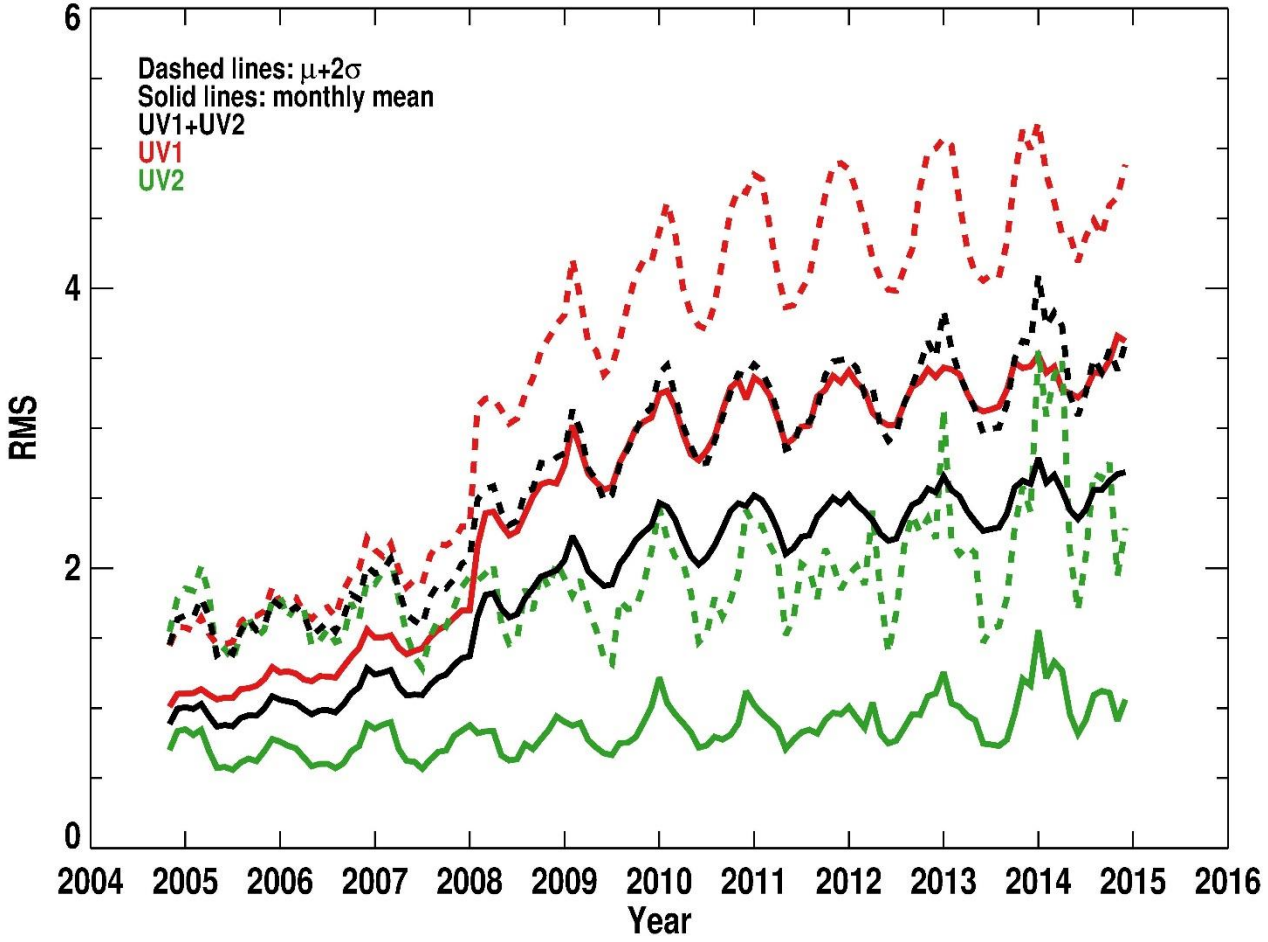
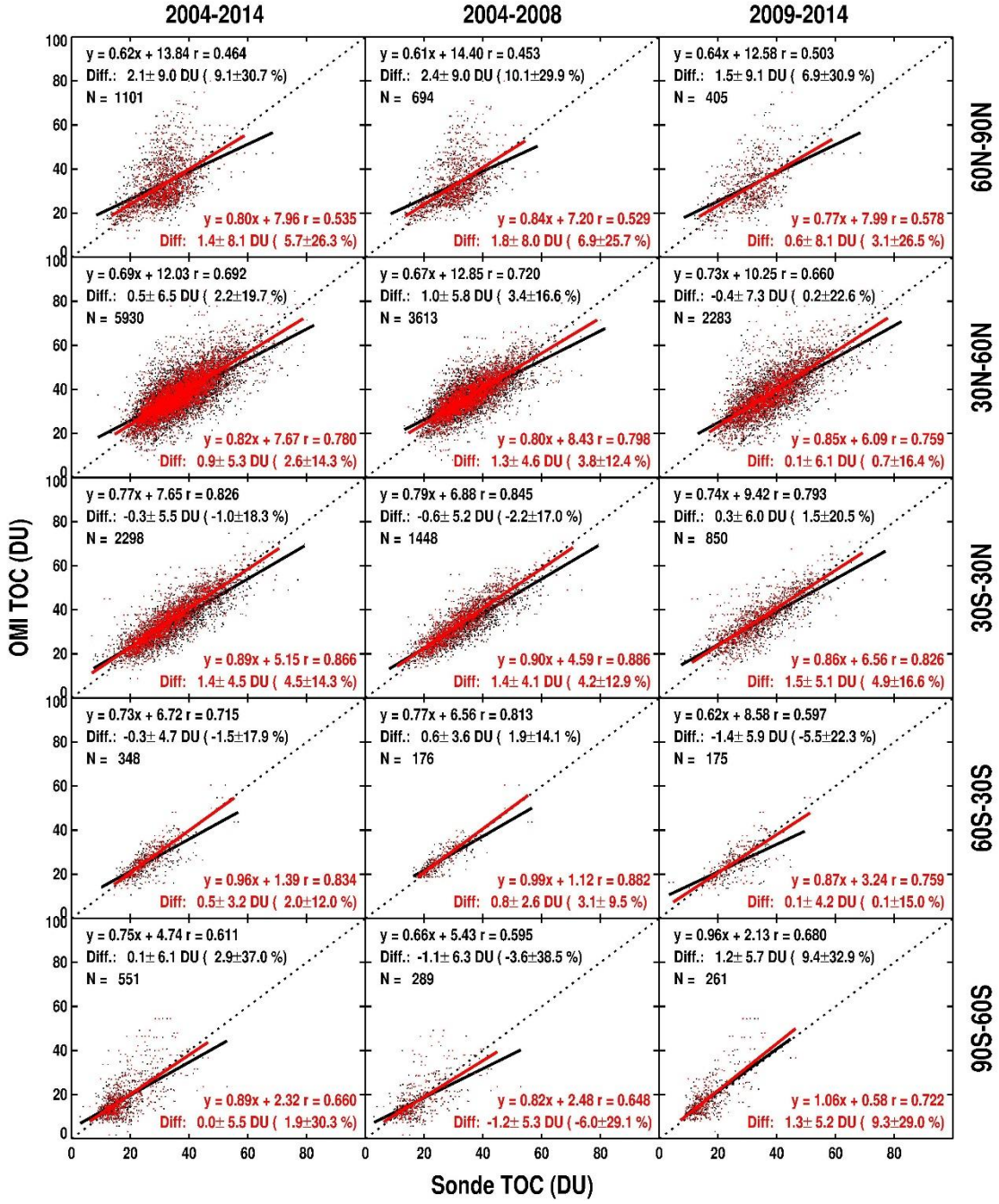


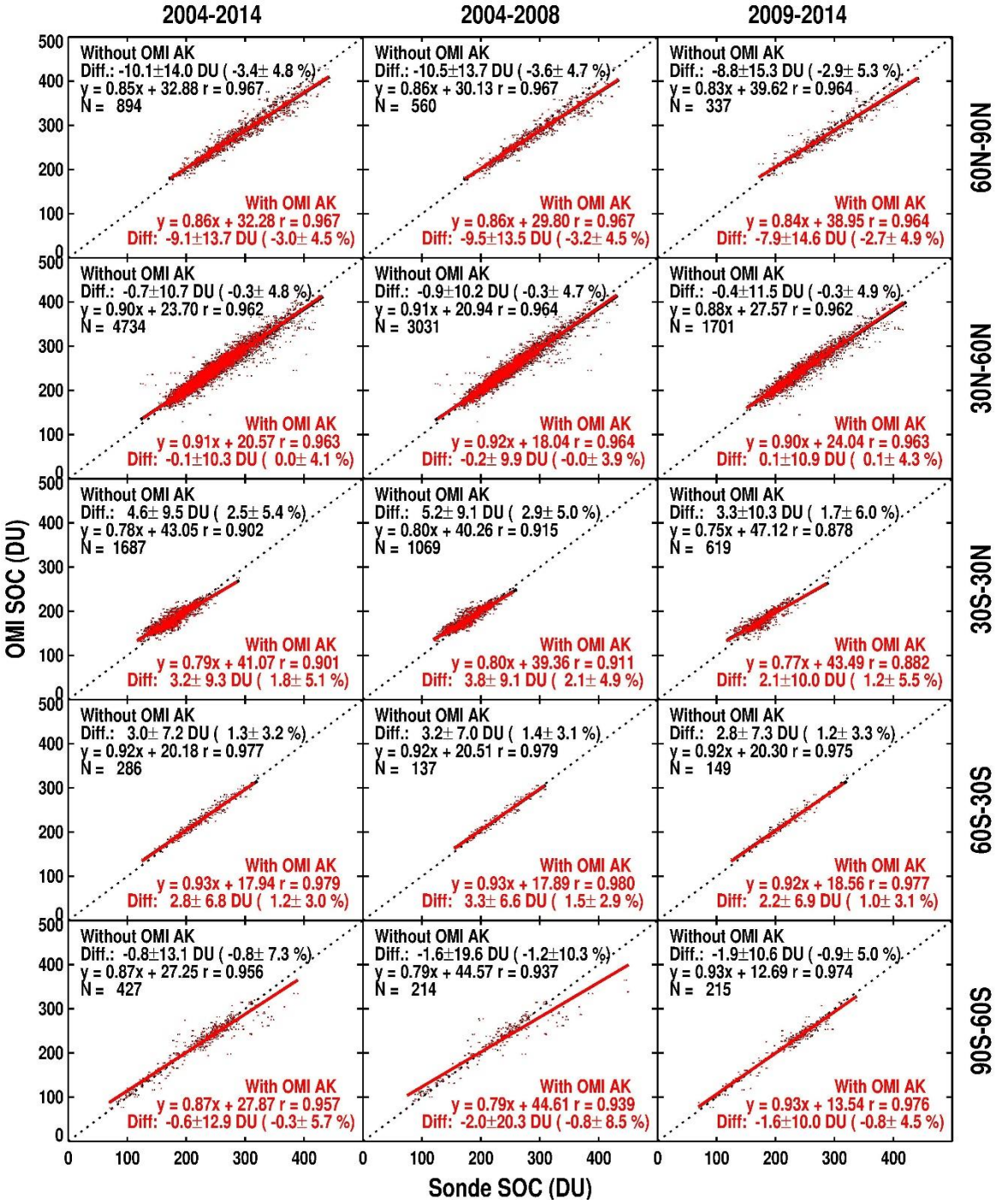
Tropospheric Ozone Column (TOC)

- TOC: surface to tropopause.
- More accurate results in mid-latitudes & tropics, with mean biases generally within 1-1.4 DU and 1σ of 3.2-5.2 DU for 2004-2014, 2.6-4.6 DU for 2004-2008, and 4.2-6.1 DU for 2009-2014.
- **Better** correlation and smaller 1σ in 2004-2008 than in 2009-2014.

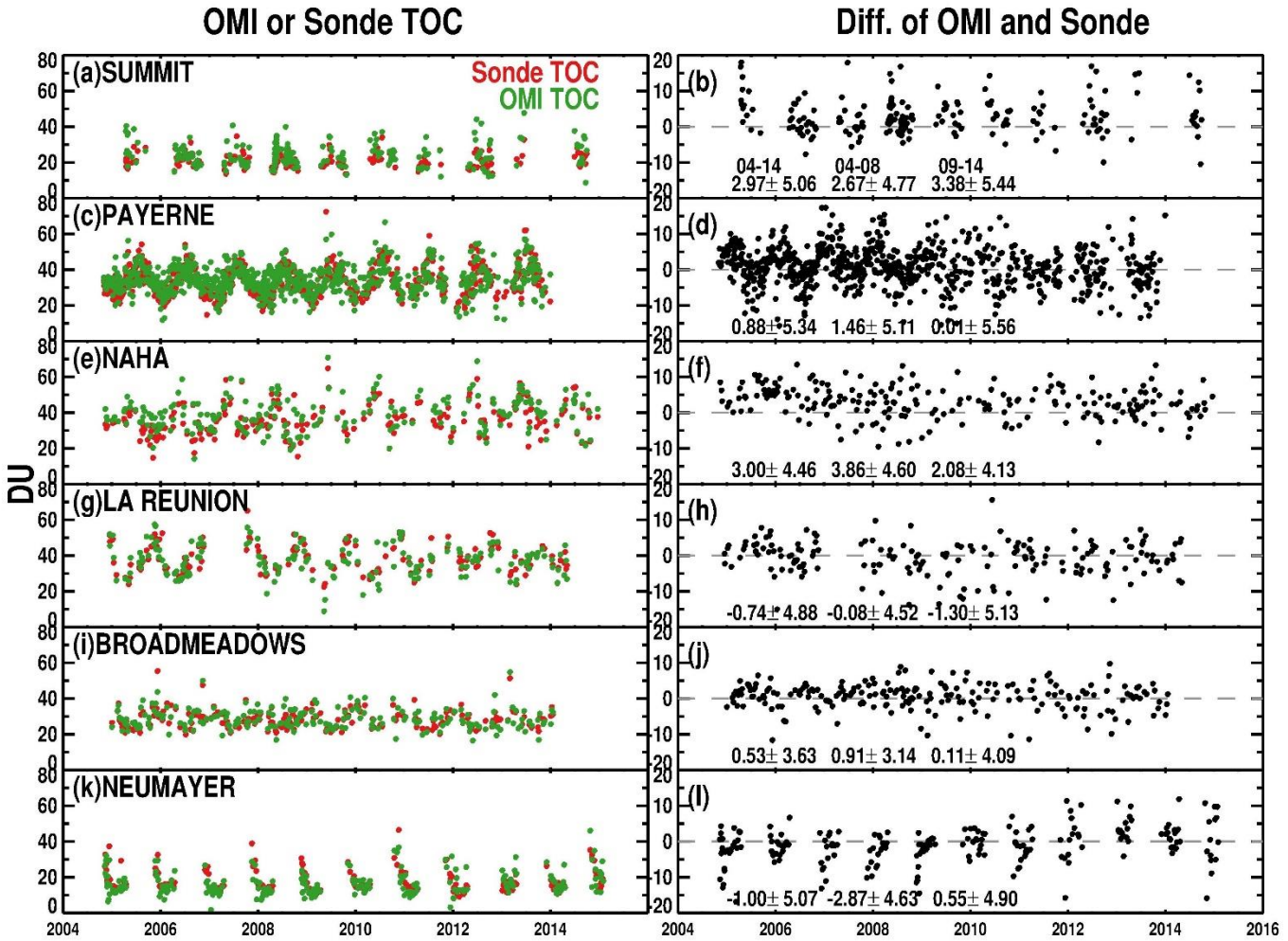


Stratospheric Ozone Column (SOC)

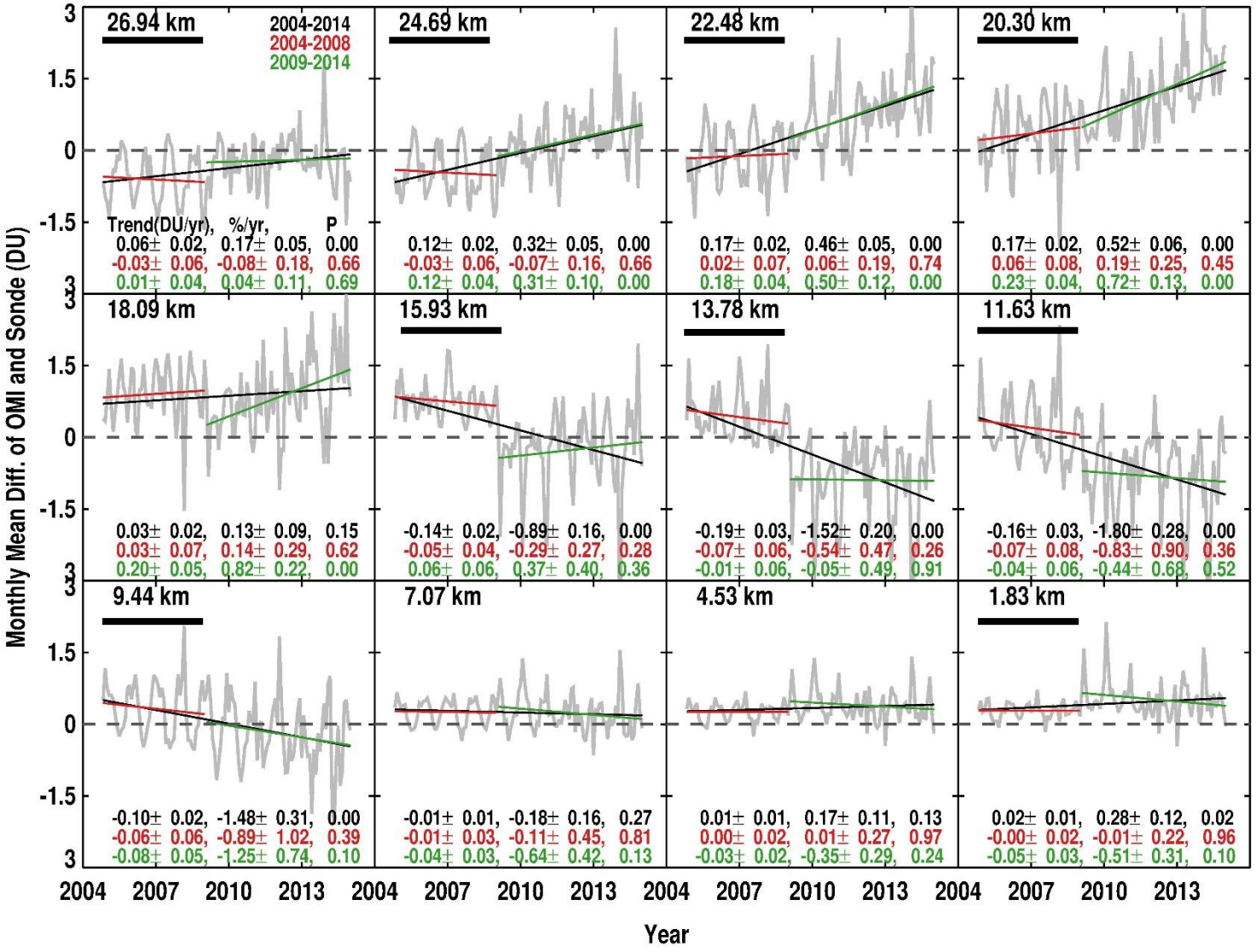
- SOC: ozone column from tropopause to <12 hPa (>~30km) including early burst balloons.
- Very good agreements with ozonesonde SOCs with R typically > 0.90 and 1σ of 4-7%
- 1σ are typically smaller for 2004-2008



OMI vs. Individual Stations

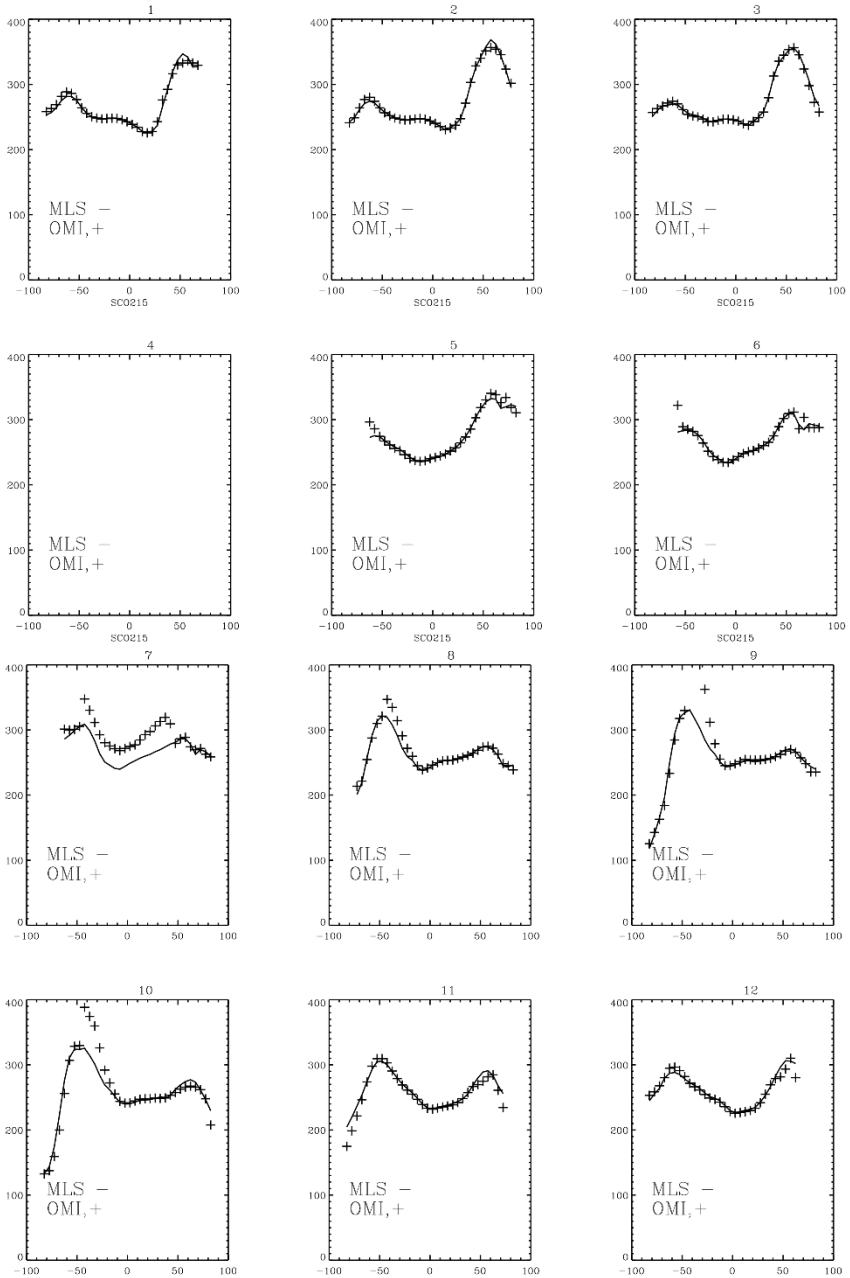


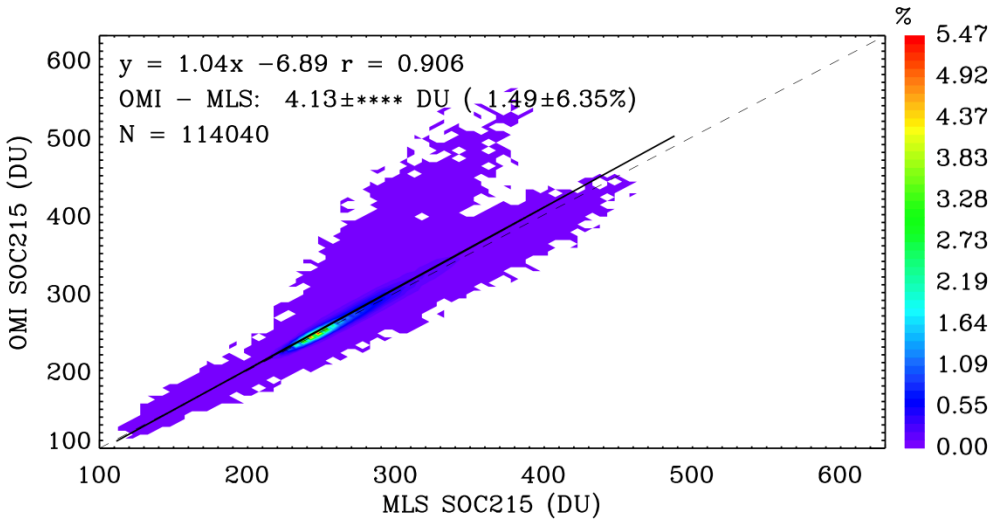
Trends of Biases at Individual OMI Levels



- Retrieval biases at individual levels show significant trends during 2004-2014 (height are marked black underline).
- 2004-2008 and 2009-2014 have different trends at most levels.
- Suggest the need to perform time-dependent soft calibration.

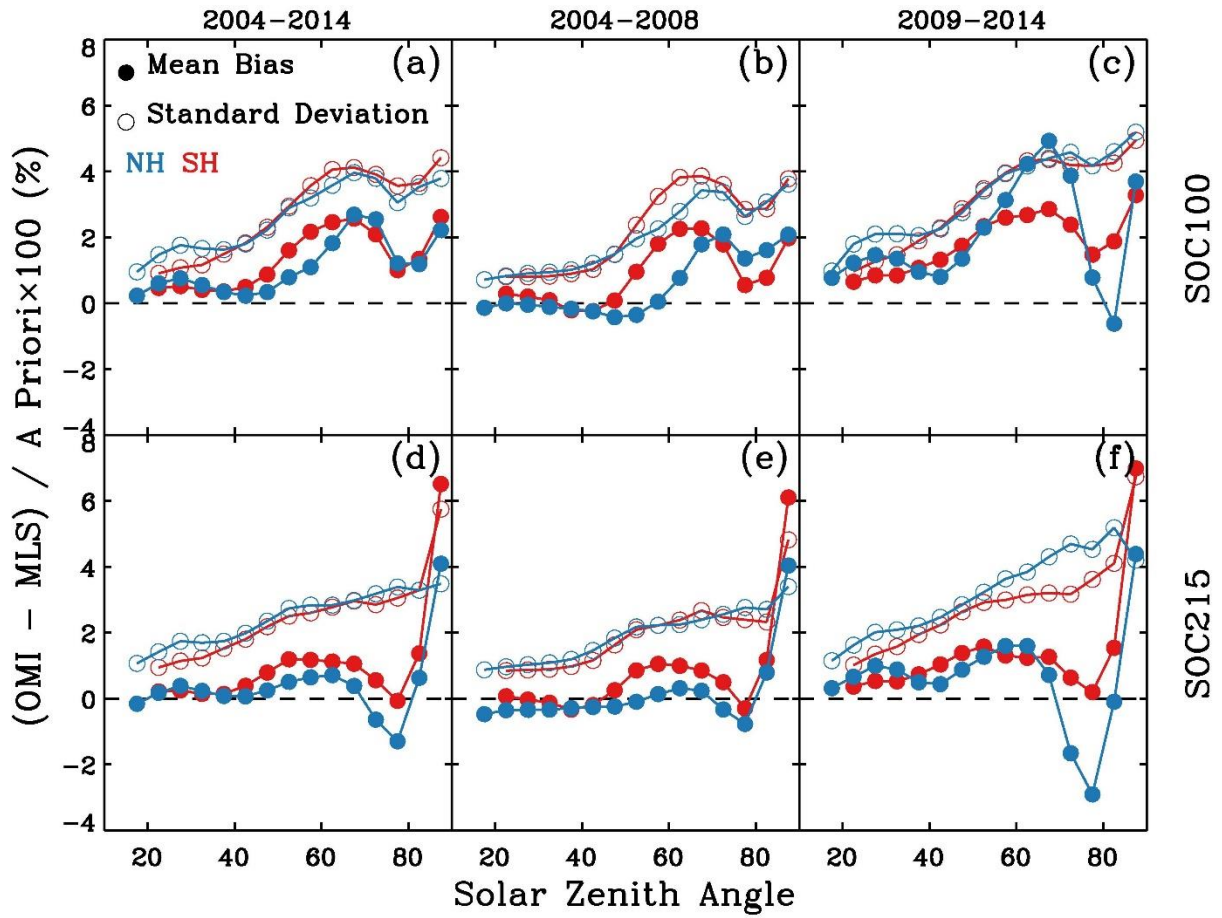
Validation with MLS in 2011



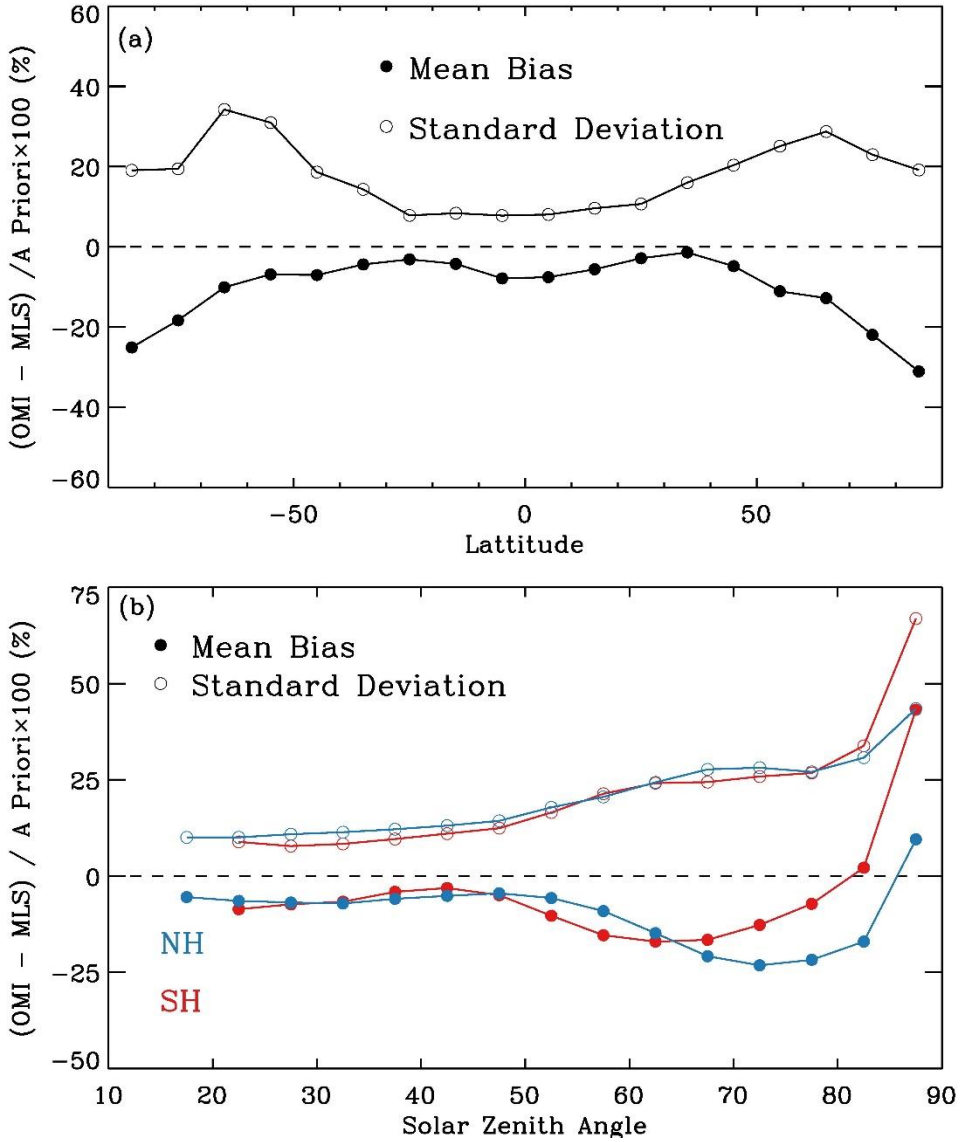


- Much larger standard deviations in SOC215 in 2011, mainly due to larger OMI biases during mostly Southern Hemisphere in July-October, likely as a result of the effects of row anomaly on UV-1 (and thus stratospheric ozone).

SOC results as a function of SZAs



MLS 261 hPa vs. OMI



Bias Trends at MLS Layers